

LWA TV on the Raspberry Pi

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1. Introduction

This article describes how to use the tiny and inexpensive Raspberry Pi computer with the Long Wavelength Array in New Mexico to observe celestial radio sources in near-real-time (LWA1, figure 1). The application was developed by the University of New Mexico (UNM) as part of LWA Education and Public Outreach. It is a good way to become familiar with the LWA, LWA TV and the Raspberry Pi, all at the same time. The LWA TV program does not allow user control, only observation, and it runs “out of the box” with no user programming whatsoever.

Abbreviations

DHCP: Dynamic Host Configuration Protocol

DVI: Digital Visual Interface

GUI: Graphical User Interface

HDMI: High Definition Media Interface

IP: Internet Protocol

LAN: Local Area Network

LWA: Long Wavelength Array

RPi: Raspberry Pi

UNM: University of New Mexico

VGA: Video Graphics Array

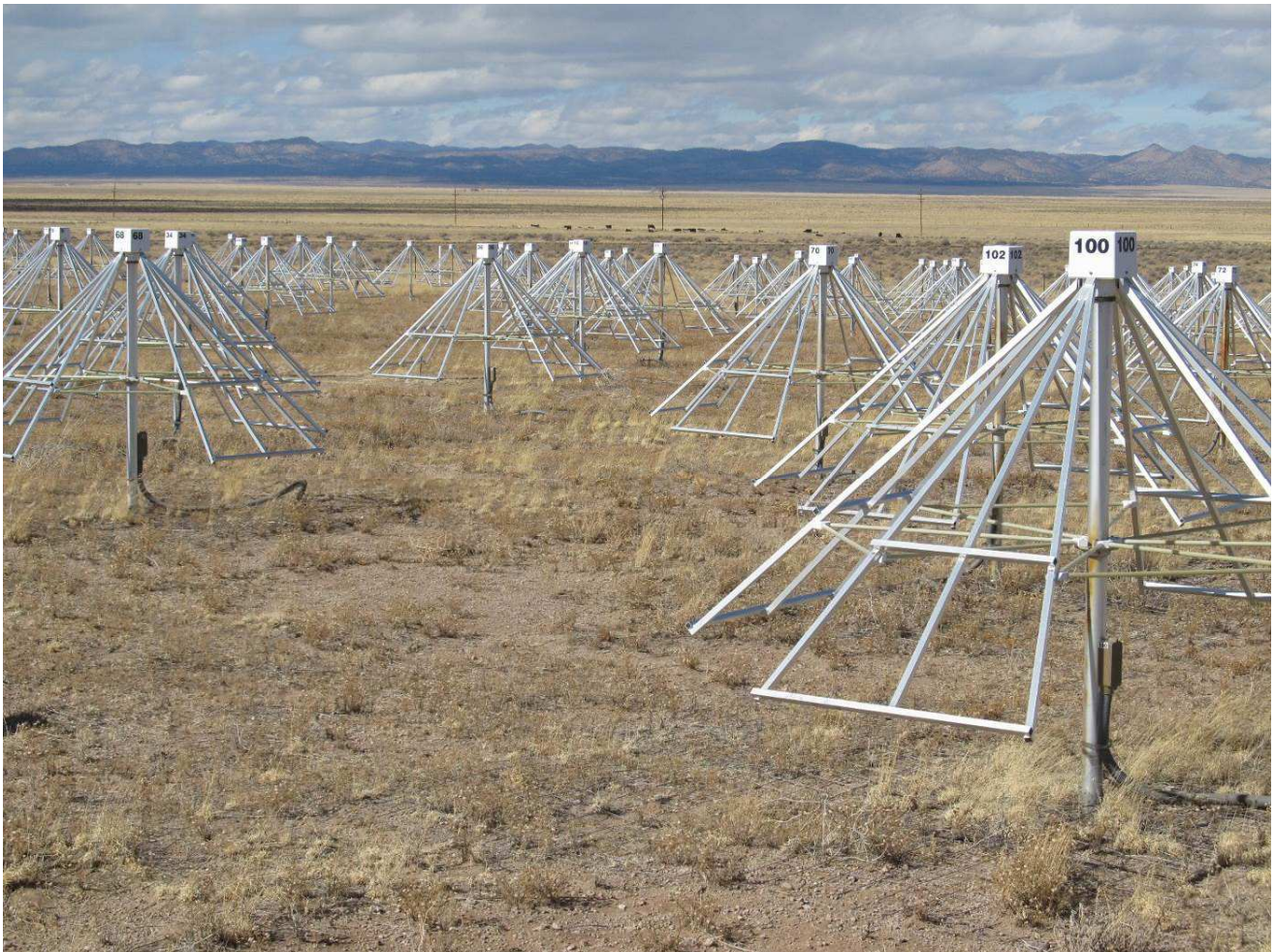


Figure 1 ~ The Long Wavelength Array in New Mexico consists of a forest of 257 crossed-dipole, tied-fork antennas. Beams are formed through signal processing to observe specific celestial radio sources or areas of the sky. (Image © 2014 W. Reeve)

One of the advantages of the approach described here is that no hardware construction or software programming is required – off-the-shelf hardware and software is all that is needed. Another advantage is that

the software for the LWA TV graphical user interface (GUI) is prepackaged by UNM and available for free. When I started working on this project (August 2014) UNM's software worked only with the Raspberry model B. I contacted Jayce Dowell at UNM and he updated the software to run on both the model B and B+ (the B+ is the latest Raspberry Pi hardware version). Although the LWA TV software is plug-and-play, there is room for some customization, which I describe in **section 5**.

I started writing this article to answer most of the questions that might arise while setting up the LWA TV application and ended up writing a reference manual. The first half provides general descriptive information and the second half contains setup details.

2. Long Wavelength Array

The LWA is used to study celestial objects or areas of the radio sky in the frequency range 10 to 90 MHz {[LWA](#)}. Its primary purpose is scientific but education and public outreach are important parts of its government-funded mission. One of the features of the LWA website is LWA TV {[LWA TV](#)} – a near real-time visual representation of the data produced by the array (figure 2).

Note: Internet links in braces { } and references in brackets [] are provided in **section 6**.

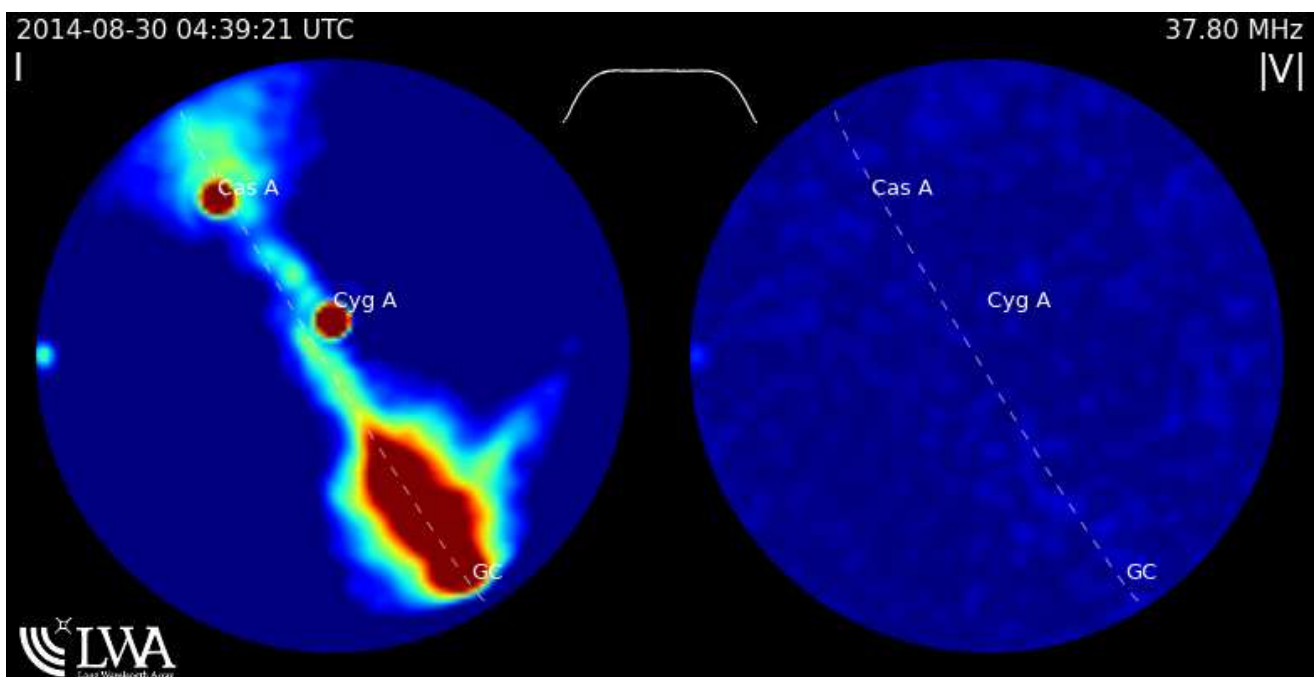


Figure 2 ~ Image from LWA TV as seen on the internet. The two circles represent the sky seen by the LWA at radio frequencies, in this case, 37.80 MHz. The horizon is along the circle edges and the zenith (straight up) is in the middle of each image. Dark blue is the background and brighter areas (in order of increasing radio intensity – blue, green, yellow, red) are the Milky Way galaxy and spots are radio sources. The locations of some of the brighter celestial radio sources are labeled. The images show total intensity (left) and intensity of circularly polarized radio waves (right). (Image source: <http://www.phys.unm.edu/~lwa/lwatv.html>)

Although LWA TV can be watched in near real-time on any PC with internet access, observers may want to setup a dedicated monitor for LWA TV and then use the PC with their own radio telescope. For example, one could observe Jupiter or the Sun with their own radio telescope using Radio-SkyPipe (RSP) or Radio-Sky Spectrograph (RSS) while watching for activity on LWA TV. This allows confirmation or correlation of observations. Of course, the radio sources would need to be in common view of the LWA and the observer's radio telescope. Another application is radio astronomy club outreach. The setup could be used at meetings, conventions and conferences. It should be noted that LWA TV itself does not allow real-time access to the actual data nor does it store any of the individual real-time images.

3. Raspberry Pi

The Raspberry Pi (abbreviated RPi throughout this article) is a small computer platform designed for educational purposes by the Raspberry Pi Foundation {[RPi](#)}. The RPi is low cost, about 35 USD (40 USD with memory card), and has HDMI video, Ethernet LAN and USB interfaces (figure 3). It is euphemistically advertised as “credit-card size” but actually is much larger. It can be plugged into an ordinary computer monitor or TV and can use a WiFi wireless access device for LAN and internet access and wireless or wired USB keyboard and mouse.



Figure 3 ~ Raspberry Pi model B and B+ hardware. The model B+ is shown in the middle with an optional clear plastic enclosure. The model B on the left is in an optional milled aluminum enclosure and is shown with a Bluetooth USB dongle. The model B on the right is in a molded clear plastic enclosure and rotated to show the opposite end. The interfaces vary slightly between the model B and B+. Enclosure dimensions are approximately 100 x 65 x 25 mm. (Image © 2014 W. Reeve)

The RPi hardware usually runs an operating system derived from Linux and (as of this writing) has become available in three versions – original model A model (not generally available in North America), model B and model B+. The model B and B+ are compared (table 1). For the LWA TV application, there is no advantage of one over the other model.

I have not tried the RPi model A, and I initially could not get the LWA TV software image provided by UNM to work on the RPi B+. I was successful only with the RPi B. All the information available from the Raspberry Pi Foundation for the model B+ insists that it is software compatible with the model B but I found there were problems that affected the LWA TV GUI. These were resolved in September 2014 and the software image now available from UNM works fine on both the B and B+.

Table 1 ~ Comparison of Raspberry Pi Model B and B+ Hardware

Description	RPi B	RPi B+
RAM	512 MB	512 MB
Memory card	SD	micro-SD
Processor system	BCM2835 SOC	BCM2835 SOC
Video 1 connector	Standard HDMI	Standard HDMI
Video 2 connector	RCA Composite	3.5 mm audio + Composite
Audio connector	3.5 mm	see Video 2
USB connector	2	4
Power connector	micro-USB	micro-USB
GPIO connector	26 pin	40 pin
Network connector	10/100 Ethernet	10/100 Ethernet
Power	5 V, ~5 W	5 V, ~3 W
Dimensions	85 x 56 x 21 mm	85 x 56 x 21 mm
Mounting	2 holes	4 holes
Cost	35 USD	35 USD

Hardware: The Raspberry Pi can be purchased from any number of suppliers worldwide. It is necessary to add a Secure Digital (SD) to the model B or micro-SD memory card to the model B+ for the LWA TV software image. Sometimes the vendor supplies a card with the RPi purchase. A card with 8 GB minimum capacity is recommended but 4 GB is sufficient. Also, an HDMI monitor is needed. A VGA monitor may be used if an HDMI-to-VGA converter (figure 4) is connected between RPi and the monitor. A keyboard with or without a mouse might be handy but is not necessary. No changes are required to the RPi platform but it should be installed in an enclosure. A Secure SHell (SSH) terminal generally is used to communicate and manage RPi from another computer on the same network. This is described in more detail in **section 5**.



Figure 4 ~ HDMI-to-VGA converter allows the RPi to be used with most computer monitors. The ones shown here cost about 10 USD. The RPi requires a full-size HDMI connector seen on the left converter. An adapter will be needed if the converter has a mini-HDMI connector as seen on the right converter. (Image © 2014 W. Reeve)

The power requirements of the RPi are modest, about 5 W for the model B and 3 W for the B+ assuming no current is being drawn from the USB ports. Because these powers are more than supplied by a standard USB port on a PC it is necessary to use an external power supply or power adapter. If no USB peripherals are used, the RPi can be powered by a well-regulated, low ripple, electrically quiet power source rated ≥ 1.0 A at 5.0 Vdc

(≥ 5 W). If the RPi USB ports are to supply power to peripherals, then a 10 W or higher power source should be used. Using a poor quality power supply will lead to unreliable operation so be sure it meets these requirements. One of the most common problems users have with the RPi is inadequate power supply current. To minimize electrical noise, it is recommended that ferrite beads be installed on the power cable (figure 5).



Figure 5 ~ AC wall power adapter with 5 V, 2.4 A (12 W) output purchased at BestBuy. One or more clamshell ferrite beads on the dc power lead help reduce radio frequency interference from the switch-mode power supply. This image shows one bead on the right with three windings of the power lead. The Raspberry Pi uses a micro-USB connector for power. (Image © 2014 W. Reeve)

Software: The RPi uses a software image that includes the operating system and applications. The RPi image developed by UNM for the LWA TV GUI is based on a Raspbian distribution. The software must be user-installed on a memory card. Installation is not difficult but it is done in a way that is not obvious to most Windows PC users. UNM provides links to web pages with the necessary procedures (see {[LWA EPO](#)}). These procedures also are briefly listed in the Software installation part of **section 5**. To make this process a little simpler, I can provide a preprogrammed micro-SD card in an SD card carrier to interested readers. See **Contact information** at the end of this article. With this memory card, the system truly is plug-and-play.

When running the LWA TV GUI software, the RPi can be used only for that purpose. However, the software is written in Python and may be modified by users if they feel “adventurous”. Python is an interpreted language and, therefore, is not compiled so nothing more than a text editor is needed to write or modify an application. Notepad++ is perfect for this purpose and is free {[Notepad++](#)}, but Windows Notepad will also work. The advantage of Notepad++ is that it automatically formats and indents the code to make it easier to read and work with.

The main piece of software in the LWA RV GUI is *lwaTV3rpi.py*, about 16.5 kB of text. Examining the code shows that it includes four command line switches, or options, which may be used to customize the GUI. The program operates normally with its default settings, and there is no compelling reason to change them except for experimental purposes. Using these options requires knowledge of the operating system and I will not discuss them further.

4. LWA TV on Raspberry Pi

The setup for LWA TV is very simple (figure 6). By default the LWA TV GUI uses the wired network interface (Ethernet) built into the RPi and acquires a network (IP) address automatically using dynamic host configuration protocol (DHCP). You can change this to a static IP address and add a WiFi interface. However, to eliminate many

potential problems, I recommend first running the LWA TV GUI in its default configuration to become familiar with it before making any changes. See **section 5** for some changes that you might find useful.

With the programmed memory card installed, make all connections before applying power to the RPi: (1) HDMI connection to your monitor or television set (be sure it is turned on); (2) Ethernet connection to your internet router; and (3) micro-USB connection to an ac power adapter. When power is applied, the RPi system automatically starts and the display will show lines of text that scroll by rather quickly. Upon completion of the boot up process, the display will momentarily blank and then the LWA TV GUI will appear. The LWA TV GUI shows the real-time images plus archived movies (figure 7). If the program is running but does not have a proper network connection, you will see “Error Downloading Image” and “Network Connection Error” on the display (figure 8). An archived movie may be running but the live portion of the display will be gray. The LWA TV GUI connects within a second or two after the network connection is established. I did not have to make any changes in my internet router for LWA TV, but if you have network connection problems your router and its firewall are the first place to start troubleshooting (after checking that the cable is plugged in).

If everything seems to be working okay it is a good idea to update both the software and the archived movies upon first use. Log into the RPi console as discussed in the RPi console part of **section 5** and execute the commands given in the Update part.

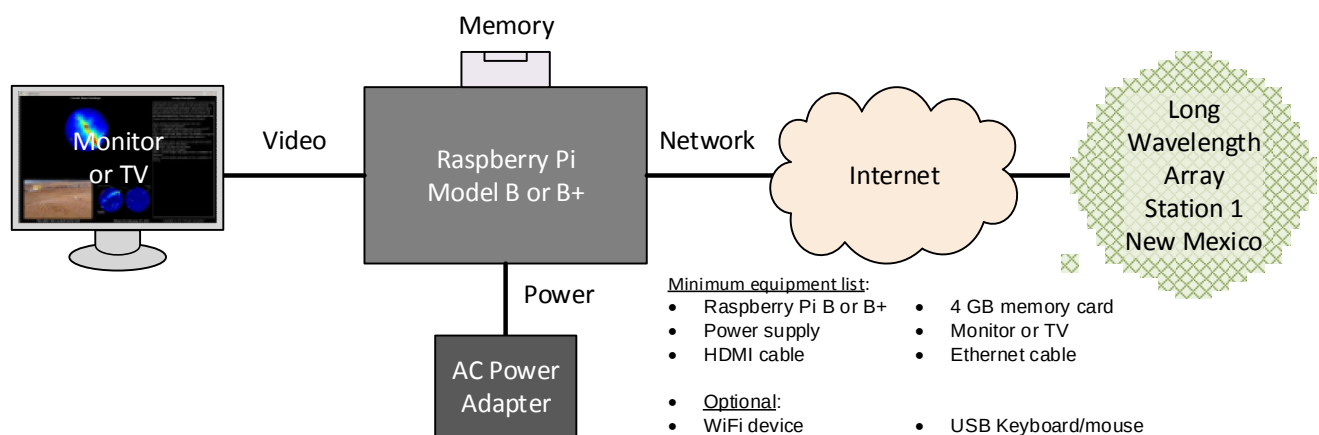


Figure 6 ~ Block diagram and equipment list for the RPi when setup for LWA TV. See text for description of each item. Before applying power to the RPi make all connections and turn on power to the monitor or television set. (Image © 2014 W. Reeve)

When connected, LWA TV downloads a daily average of approximately 25 kB/s, 91 MB/h or 2.2 GB/d. The internet traffic is split between the real-time images and archived movies. The LWA station processes the data and prepares images in near real-time. The LWA TV GUI checks for and downloads a new image every 5 s. Each image includes the total radio energy received during the 5 s interval, so transient emissions lasting less than 5 s are recorded. The images are about 120 kB each so the average network traffic load is about 24 kB/s. The archived movies are downloaded in the evening and are usually around 100 MB each. Downloading uses whatever internet bandwidth is available.

If your internet service has download limits and imposes penalties when exceeded, it would be wise to monitor your usage closely. If you want to reduce the internet usage overnight or other times, you can simply unplug the Ethernet cable rather than shutting down the RPi. If you use a wireless network connection, you will need to use a software method to stop network usage. The LWA TV application updates the movie archive cache at 1830 in the time zone used by the RPi. By default, the LWA TV software uses mountain daylight time (MDT) but both the time zone and movie cache update time can be changed. See [Date, time and time zone](#) in **section 5** for these and a method to suspend the software at night or outside normal observation times to reduce network usage.

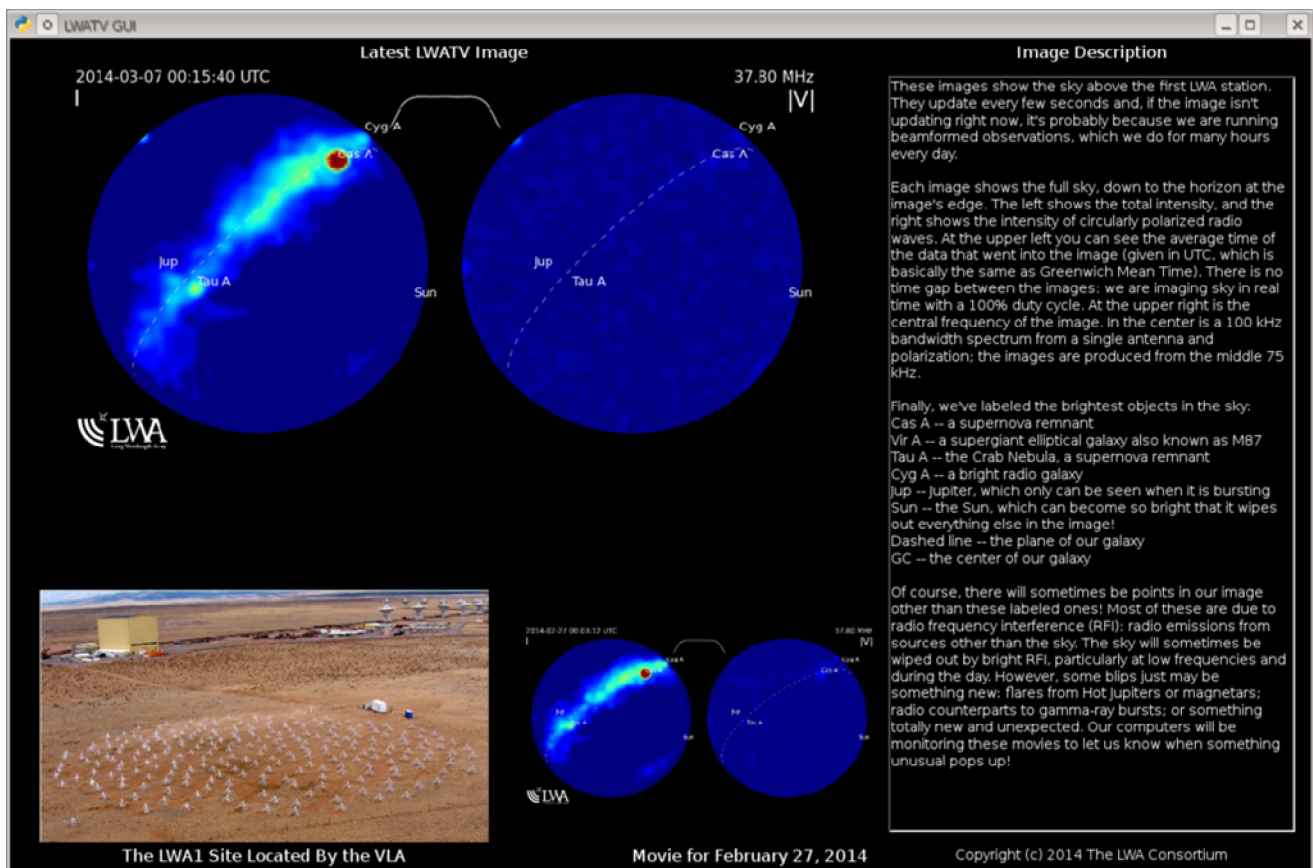


Figure 7 ~ LWA TV screen. The live image at top-left shows one or two circles depending on the current LWA operating mode. When LWA is setup for beam pointing, only one circle may appear as shown here; otherwise, two appear. The two circles at bottom-middle are archive movies from the previous several days. The movies cover a full day, often with gaps, and each requires about 12 minutes to run. Sometimes radio frequency interference is seen along the edges of the circles. The aerial image of the LWA at lower-left is fixed and text on right changes depending on normal or beam-pointing view of the live image. (Image source: <http://fornax.phys.unm.edu/lwa/trac/wiki/EPO>)

5. Installation and Operation Notes

This section provides information that will help first-time users. It is focused on the LWA TV application.

Software installation: The brief instructions here assume the reader is using a Windows PC to install the LWA TV GUI software on the memory card: (1) Install 7-Zip [{7-Zip}](#), SD Formatter [{SDFmt}](#) and Win32 Disk Imager

{[WDImg](#)} on the Windows PC. When running the latter two programs, run them as Administrator; (2) Put the memory card in a card reader (see [Note](#) below) connected to the PC and use SD Formatter to format the card. In SD Formatter set the Options to Format Type = Full Erase and Format Size Adjustment = On; (3) Download the LWA TV GUI software image for the RPi from [LWASoft](#). The file is compressed so decompress it with 7-Zip to a raw image file (*.img). This will take a few minutes; (4) Write the software image to the memory card with Win32 Disk Imager using its default settings. This will take a few minutes. After the Write operation is finished, the memory card is ready to use in the RPi. Be sure RPi power is OFF and insert the card. Note: Some micro-SD cards and card readers are incompatible, so it is best to install the micro-SD card in a full-size SD card carrier, insert the carrier into the reader and then format the card and load the software image.

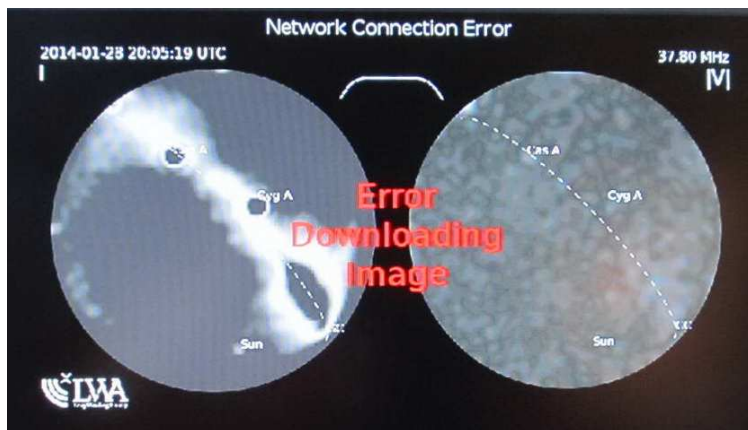


Figure 8 ~ If there is a network connection problem, the live globes are gray and warnings appear. During normal operation, the Error Downloading Image message may momentarily appear but it is nothing to worry about if it happens only occasionally. (Image © 2014 W. Reeve)

The RPi model B uses an ordinary push-to-insert/pull-to-release slot connector whereas the model B+ uses a push-to-insert/push-to-release slot connector. When the RPi is powered ON, the software will load and run automatically.

RPi console: In order to make changes to the RPi setup (described later in this section), it is necessary to log into the RPi console. This may be done from a Windows PC that is on the same network as the RPi. or through a wireless or wired keyboard. The RPi uses secure shell (SSH) for console communications so it is necessary to install an SSH client application such as {[PuTTY](#)} or {[TeraTerm](#)} on your PC if using the network connection.

To use SSH, first determine the IP address assigned to the RPi by your internet router. Procedures vary widely and it is best to read your router user manual or search for online help. The RPi host name is "lwatvgui" (without quotes) and will be identified as such in your router's local network status screen. An alternate, and perhaps quicker, method is to download and install on a Windows PC a network scan program as described at [RPiNet](#).

For PuTTY place the RPi IP address into the Host Name or IP address field and click Open (figure 9). After authentication you will see the RPi login prompt. The default username is "pi" (without quotes). After you enter the username, RPi will ask for the password. For obvious reasons I will not publish the password here, but it can be obtained by emailing the address given at the very bottom of [LWA EPO](#).

Updates: To update the LWA TV software and archived movie cache, send the following commands one at a time using the SSH terminal described above. Wait for each process to complete before entering the next command. It is necessary to send these commands only upon first use of the LWA TV GUI image:

```
cd ~/LWATV/
svn update
./updateMovies.py -v
sudo rpi-update
sudo reboot
```

It is a good idea to routinely update the Raspbian software distribution as well. Send the following commands with an SSH terminal to update the non-LWA TV software (these updates and upgrades can require tens of minutes if new distributions have become available after the last update):

```
sudo apt-get update
sudo apt-get upgrade
```

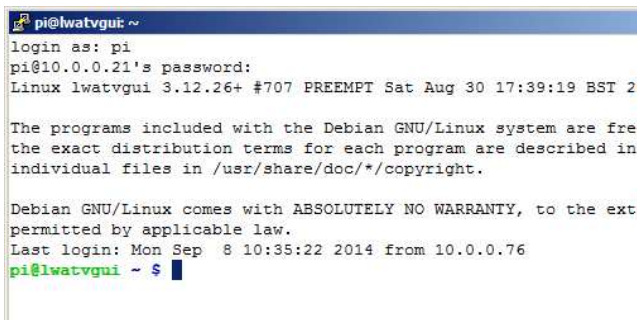
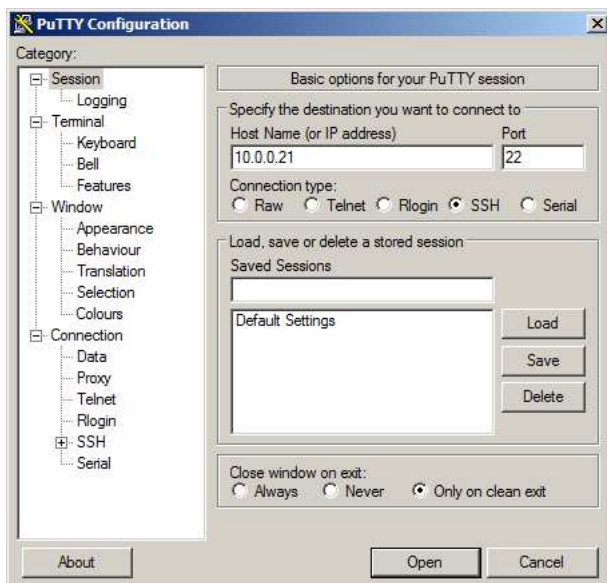


Figure 9 ~ Upper-left: Screenshot of PuTTY configuration window with the IP address for one of my setups. Upper-right: Upon first connection, PuTTY asks for authentication. Lower-left: When PuTTY is connected, the window changes to a simple command line interface. After login, you can make changes to the RPi. (Images © 2014 W. Reeve)

Documentation: Online documentation for the Raspberry Pi including troubleshooting information is available at [{RPIDoc}](#) and [{RPIHub}](#). There also are numerous forums that have information related to RPi. The only documentation that exists for the LWA TV application is this article and information at [{LWA EPO}](#).

Keyboard-mouse: The LWA TV GUI has built-in drivers for a USB keyboard and mouse but they are not required for normal operation. However, a keyboard is nice to have if you need to directly access the RPi or cannot access it indirectly using SSH as described above. Small wired or wireless keyboards, with or without a mouse (figure 10), are available from [{Adafruit}](#).



Figure 10 ~.Wireless keyboard and mouse uses a Bluetooth connection. The keyboard is about 285 mm long. A Bluetooth dongle is included and requires one USB port as seen on the left of the RPi model B in the image. (Image © 2014 W. Reeve)

Heat: The RPi processor normally runs warm but not hot. While using LWA TV I measured about 30 °C using an infrared non-contact thermometer pointed at the processor chip.

Enclosure: Many different types of enclosures are available for the model B and B+ RPi, but the enclosures for one model do not fit the other. Most enclosures are plastic and provide no shielding whatsoever. This might be of concern where the RPi is used near a radio telescope antenna or receiver. An expensive aluminum enclosure is available for the model B, and it should provide better shielding.

Radio frequency interference: I took some measurements with a spectrum analyzer and a shielded magnetic loop probe and electric field probe and found several spectral spikes in the high MF and low HF ranges, about 1.5 to 8 MHz or so. These were apparent only when the probes were held against the clear plastic enclosure of the model B+. I checked up to several hundred MHz but found no other indications. I did not make any measurements with the aluminum enclosure on the model B. It should be noted that conducted interference in connecting cables often is radiated because the cables act like antennas, so each installation will have different RFI characteristics and it may be necessary to install ferrite beads on all connecting cables.

Video monitor: The RPi uses a standard HDMI connector for video. It may be used with a monitor or TV with an HDMI input. It also may be used with a VGA monitor by using an HDMI-to-VGA converter or with a DVI monitor or TV with an HDMI-to-DVI converter. I experimented with the HDMI and VGA interfaces on monitors and televisions but did not attempt to use DVI. For portable use, say at a convention, a small screen monitor would be handy. Many compatible types are available; for example, search “monitor” at [Adafruit](#) to see a variety of 5.6, 7 and 10.1 in monitors with HDMI inputs. I have not tried any monitors/TVs except those discussed below.

I initially connected the RPi to the HDMI port on a Hannspree HF-199 monitor. The HF-199 has HDMI and VGA input connectors, and its maximum resolution is WXGA+ (1440x900 pixels, 16:10 aspect ratio). I found that the displayed image was slightly elongated horizontally when using the LWA TV GUI default settings.

To change the video settings, it is necessary to edit the config.txt file in the /boot/ folder of the RPi. It is best to do a little research on the internet before making any changes. Use *nano* to edit the file (nano is a simple text editor built-into the software image):

```
sudo nano /boot/config.txt
```

After making the desired changes and saving the file, reboot the RPi:

```
sudo reboot
```

I tried changing the RPi video settings to different screen resolutions and eventually found that only one HDMI mode provided a better display and that was at the monitor's maximum resolution 1440x900 (hdmi_group=2, hdmi_mode=47). However, at this high resolution, the real-time display and archive movies sometimes would momentarily stall or skip.

I then tried an HDMI-to-VGA converter on the monitor's VGA input and could not obtain a good display. With many settings I had no display at all. I spent about one full day trying different port settings on the monitor and RPi. I finally gave up and settled on using only the monitor's HDMI port. This monitor works very well at 1440x900 pixel resolution with the VGA interface on the lab PC.

I also tried our Philips 47 in LCD television set. This TV has three HDMI ports and supports several resolutions, 480p, 720p, 1080p and 1080i. I found I could obtain a nice picture using RPi settings for 720p (hdmi_group=1, hdmi_mode=4) and overscan (overscan_right=40, overscan_left=40, overscan_top=16, overscan_bottom=16) (figure 11). Although this TV supports 1080p and 1080i, I could not find any RPi overscan settings that provided a properly positioned horizontal display. Based on my experience so far, I think the video interface implementation is the RPi's biggest shortcoming (the video implementation is separate from the LWA TV GUI). Perhaps with enough time and experimentation, I could make it work better at different resolutions.

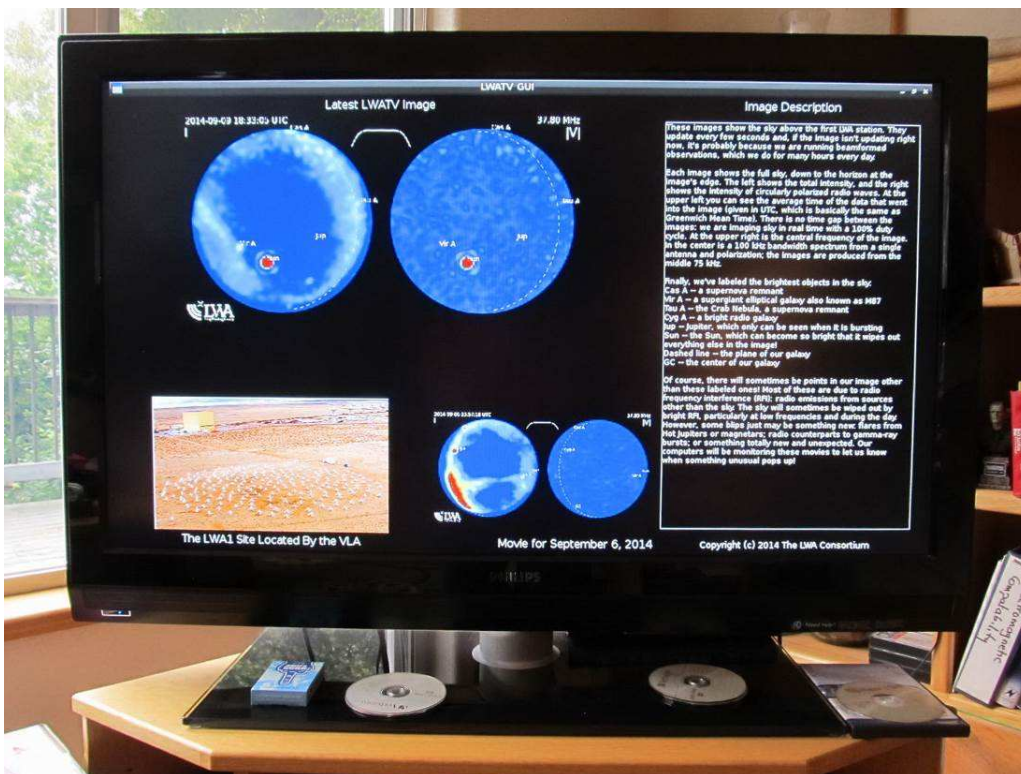


Figure 11 ~ Philips 47 in LCD television set connected through one of its HDMI ports to the RPi. The RPi HDMI port was set for 720p resolution (see text). (Image © 2014 W. Reeve)

As a final video test, I connected a Dynex 19 in LED-LCD TV that I use in the lab. This is a small set designed as a kitchen counter TV with a wide range of video inputs. After using the TV menu to select the HDMI port, the screen immediately showed the correct display. I made no changes in the RPi video settings (720p) used with the 47 in TV previously described.

Date, time and time zone: By default, the Raspbian distribution uses Network Time Protocol (NTP) to automatically set the RPi time when it is connected to the internet. The RPi does not have a real-time clock or battery backup, so it must be running and connected to the internet to correctly set time and date. To confirm the date, time and time zone, enter the following at the RPi prompt on the SSH terminal:

```
date
```

To change the time zone, enter the following. The displayed instructions will lead you through the reconfiguration:

```
sudo dpkg-reconfigure tzdata
```

To confirm the scheduled download time for the daily LWA TV movie archive update, enter the following to see what is in the cron table (*cron* is a utility that runs automatically in the background at specified times):

```
crontab -l
```

You should see a number of comments with the last two lines as follows:

```
# m h dom mon dow   command
30 18 * * * python ~pi/LWATV/updateMovies.py
```

The last line is the scheduled event with a time of 1830 in the system time zone. It is shown in crontab with minutes before the hour. To change the scheduled time, enter the following to edit the cron table. This will invoke the default editor and allow you to change the time in the table. Do not change anything on the last line except the minutes and hour:

```
crontab -e
```

The crontab function also can be used to temporarily stop and then restart the LWA TV application software at regular intervals to reduce network usage. For example, you could use a stop process at a specified time, say 2200 in the evening, and then a start process the next morning at 0700. The stop and start times can be set as required and are easy to change depending on observation activities. Each hour the software is suspended will reduce network usage by about 91 MB. It will be necessary to coordinate the start and stop times with the movie update time discussed above. To use the suspension feature, add the following three lines to the cron table using the cron table editor (*crontab -e*). The lines shown here will start the program at 0700 and stop it at 2200:

```
DISPLAY="":0"
0 7 * * * python ~pi/LWATV/lwatv3.rpi.py
0 22 * * * pkill -f lwatv3.rpi.py
```

When using this feature, the RPi must be running and connected to the network. Simply delete the lines if you later change your mind about using the suspension feature.

Static IP and WiFi: To setup a static IP address, see Appendix A, and to setup WiFi, see Appendix B. These procedures are similar to those found here: [{RPiWi-Fi}](#) and [{RPiIP}](#).

The RPi works fine with both the Ethernet and WiFi connections enabled and it is not necessary to unplug one when using the other. You will need a WiFi dongle (figure 12). I purchased one from [{Adafruit}](#). It should be remembered that a wireless dongle derives power from the RPi USB port and this power is in addition to that required by the RPi itself. The dongle should be plugged into the USB port before power is applied to the RPi; otherwise, the RPi will reboot because of the momentary voltage drop on its power bus. This is a design deficiency in the RPi.



Figure 12 ~.WiFi dongle provides wireless access and uses one USB port. I found the distance from the RPi to the wireless access point to be surprisingly good (> 3 m) in spite of its very small antenna. (Image source unknown)

The following commands can be used to check the quality of the wireless connection after it has been setup:

```
sudo iwlist wlan0 scan
```

or

```
sudo iwconfig
```

Downtime: Sometimes the LWA TV does not seem to be working or the display does not properly render the archive movies or live presentation. You may see “Error Downloading Image” and “Network Connection Error” on the display for brief periods. This does not appear to be a fault with the RPi but possibly with the network connection or the UNM server and related maintenance activities. It also may occur during the transition from normal view to beam pointing view at LWA1. The outages do not last long, maybe tens of minutes at most, and always self-corrected (in other words, I just let the RPi run and never rebooted it). If you suspect your WiFi connection, confirm connectivity as described in the previous item.

Backup: You will want to backup your memory card after any major changes. You will need this backup if you corrupt the program so badly that it will not boot. There are several ways to run a backup. If you are a Windows user, you can use Win32DiskImager, the same program used to *Write* the image to the memory card in the first place. However, to backup, you will *Read* the image. This method requires removing the SD card from the RPi and then inserting it in a card reader connected to the Windows PC. Be sure to shutdown the RPi before removing the memory card (see next item).

Shutdown the RPi: To avoid corrupting the RPi software, the system must be properly shutdown before removing power (just like a Windows PC). This may be done from a keyboard connected to the RPi by pressing CTRL-ALT-F1 to invoke the console directly on the display, or by using an SSH client on a PC. Log into RPi at the prompts and then enter;

```
sudo shutdown -h now
```

or

```
sudo halt
```

The display will indicate the shutdown process. All LED indicators except the red power LED on the RPi board will extinguish when the shutdown is complete. Power may then be removed. If you are at the console and change your mind before entering the shutdown commands, press CTRL-ALT-F7 to return to LWA TV.

6. References and Web Links

{7-Zip}	http://www.7-zip.org/
{Adafruit}	http://www.adafruit.com/
{LWA}	http://www.phys.unm.edu/~lwa/index.html
{LWA TV}	http://www.phys.unm.edu/~lwa/lwatv.html
{LWA EPO}	http://fornax.phys.unm.edu/lwa/trac/wiki/EPO
{LWASoft}	http://fornax.phys.unm.edu/lwa/trac/downloads/
{Notepad++}	http://notepad-plus-plus.org/
{PuTTY}	http://www.putty.org/
{RPi}	http://www.raspberrypi.org/
{RPiDoc}	http://www.raspberrypi.org/documentation/
{RPiHub}	http://elinux.org/RPi_Hub
{RPiNet}	http://www.cpdforteachers.com/resources/finding-the-ip-address-of-your-raspberry-pi
{RPiIP}	https://www.modmypi.com/blog/tutorial-how-to-give-your-raspberry-pi-a-static-ip-address
{RPiWi-Fi}	http://www.howtogeek.com/167425/how-to-setup-wi-fi-on-your-raspberry-pi-via-the-command-line/
{SDFmt}	https://www.sdcard.org/downloads/formatter_4/
{TeraTerm}	http://ttssh2.sourceforge.jp/index.html.en
{WDImg}	http://sourceforge.net/projects/win32diskimager/

Acknowledgement

Jayce Dowell at UNM helped me immensely with this project, and I hereby extend my thanks and appreciation. The ratio of Jayce's knowledge of the Raspberry Pi and LWA to my knowledge is very close to infinity/zero.

Contact Information for Preprogrammed Memory Card

A preprogrammed micro-SD memory card may be ordered by emailing:

OrderInfo@reeve.com

The micro-SD card includes an SD carrier and will work in either the Raspberry Pi model B or B+. The cost is 15 USD including postage to any US destination and most other countries.

Appendix A ~ Change from DHCP to Static IP Address

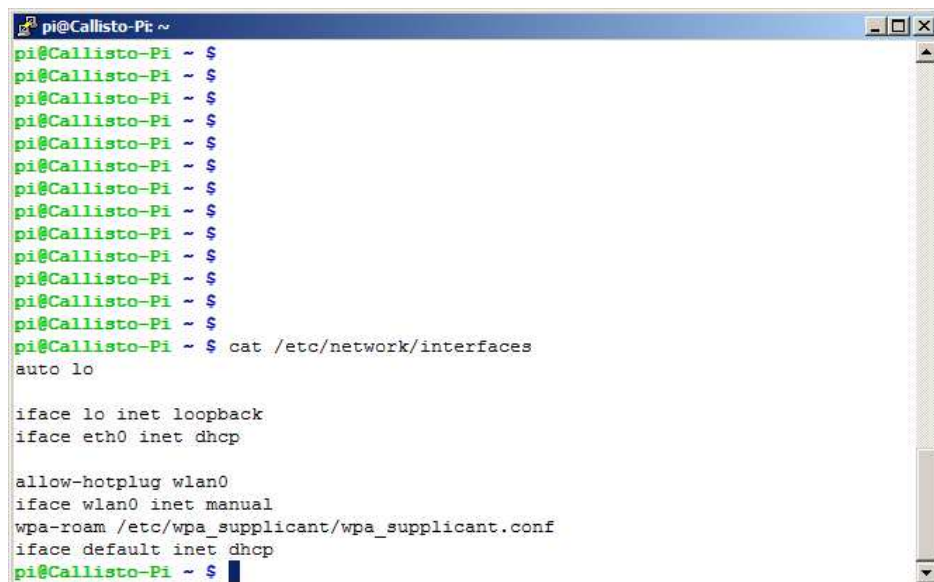
To log into the RPi console, you need its IP address. By default, RPi obtains the address automatically from the LAN router using DHCP. However, the address can change whenever the RPi is removed from the network or turned off. It may be preferable to operate the RPi with a static IP address, an address that never changes. For one thing, it simplifies connection to the RPi console from an SSH terminal because the address is always known.

The following steps assume the RPi is connected to the LAN through a wired Ethernet interface. As you go through the following steps, take screenshots before and after making changes – this will help in case you need to reverse your changes.

A.1. Check the existing setup

Log into the RPi using PuTTY and enter the following at the prompt. The default user and password is “pi” and “Callisto_X!” without quotes:

```
cat /etc/network/interfaces
```

A screenshot of a terminal window titled 'pi@Callisto-Pi ~'. The terminal shows the output of the command 'cat /etc/network/interfaces'. The output is as follows:

```
pi@Callisto-Pi ~ $  
pi@Callisto-Pi ~ $  
pi@Callisto-Pi ~ $  
pi@Callisto-Pi ~ $  
pi@Callisto-Pi ~ $  
pi@Callisto-Pi ~ $  
pi@Callisto-Pi ~ $  
pi@Callisto-Pi ~ $  
pi@Callisto-Pi ~ $  
pi@Callisto-Pi ~ $  
pi@Callisto-Pi ~ $  
pi@Callisto-Pi ~ $  
pi@Callisto-Pi ~ $  
pi@Callisto-Pi ~ $  
pi@Callisto-Pi ~ $ cat /etc/network/interfaces  
auto lo  
  
iface lo inet loopback  
iface eth0 inet dhcp  
  
allow-hotplug wlan0  
iface wlan0 inet manual  
wpa-roam /etc/wpa_supplicant/wpa_supplicant.conf  
iface default inet dhcp  
pi@Callisto-Pi ~ $
```

Note the line that indicates the interface named eth0 uses DHCP:

```
iface eth0 inet dhcp
```

Enter the following at the prompt:

```
ifconfig
```

```
pi@Callisto-Pi ~  
iface eth0 inet dhcp  
  
allow-hotplug wlan0  
iface wlan0 inet manual  
wpa-roam /etc/wpa_supplicant/wpa_supplicant.conf  
iface default inet dhcp  
pi@Callisto-Pi ~ $ ifconfig  
eth0      Link encap:Ethernet  HWaddr b8:27:eb:13:40:76  
          inet addr:10.0.0.11  Bcast:10.0.0.255  Mask:255.255.255.0  
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1  
          RX packets:199383 errors:0 dropped:0 overruns:0 frame:0  
          TX packets:193416 errors:0 dropped:0 overruns:0 carrier:0  
          collisions:0 txqueuelen:1000  
          RX bytes:34234687 (32.6 MiB)  TX bytes:43215623 (41.2 MiB)  
  
lo        Link encap:Local Loopback  
          inet addr:127.0.0.1  Mask:255.0.0.0  
          UP LOOPBACK RUNNING  MTU:65536  Metric:1  
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0  
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0  
          collisions:0 txqueuelen:0  
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)  
  
pi@Callisto-Pi ~ $
```

Note the information to the right of eth0:

eth0 **Link encap:Ethernet** **HWaddr b8:27:eb:13:40:76**
 inet addr:10.0.0.11 **Bcast:10.0.0.255** **Mask:255.255.255.0**

In the above example:

inet addr: 10.0.0.11 (current IP address, example)
Bcast: 10.0.0.255 (broadcast IP range, example)
Mask: 255.255.255.0 (subnet mask, example)

Your console screen most likely will show different values. Copy the following details from your console:

inet addr: _____ (your current IP address)
Bcast: _____ (your broadcast IP range)
Mask: _____ (your subnet mask)

Now enter the following at the prompt:

`netstat -nr`

```
pi@Callisto-Pi ~  
iface default inet dhcp  
pi@Callisto-Pi ~ $ ifconfig  
eth0      Link encap:Ethernet  HWaddr b8:27:eb:13:40:76  
          inet addr:10.0.0.11  Bcast:10.0.0.255  Mask:255.255.255.0  
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1  
          RX packets:199383 errors:0 dropped:0 overruns:0 frame:0  
          TX packets:193416 errors:0 dropped:0 overruns:0 carrier:0  
          collisions:0 txqueuelen:1000  
          RX bytes:34234687 (32.6 MiB)  TX bytes:43215623 (41.2 MiB)  
  
lo        Link encap:Local Loopback  
          inet addr:127.0.0.1  Mask:255.0.0.0  
          UP LOOPBACK RUNNING  MTU:65536  Metric:1  
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0  
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0  
          collisions:0 txqueuelen:0  
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)  
  
pi@Callisto-Pi ~ $ netstat -nr  
Kernel IP routing table  
Destination      Gateway          Genmask         Flags   MSS Window  irtt Iface  
0.0.0.0          10.0.0.1        0.0.0.0         UG      0 0        0 eth0  
10.0.0.0         0.0.0.0         255.255.255.0   U       0 0        0 eth0  
pi@Callisto-Pi ~ $
```

Note the information shown in the Destination and Gateway columns:

Destination: 10.0.0.0 (network destination)

Gateway: 10.0.0.1 (gateway address)

Your console screen most likely will show different values. Copy the following details from your console:

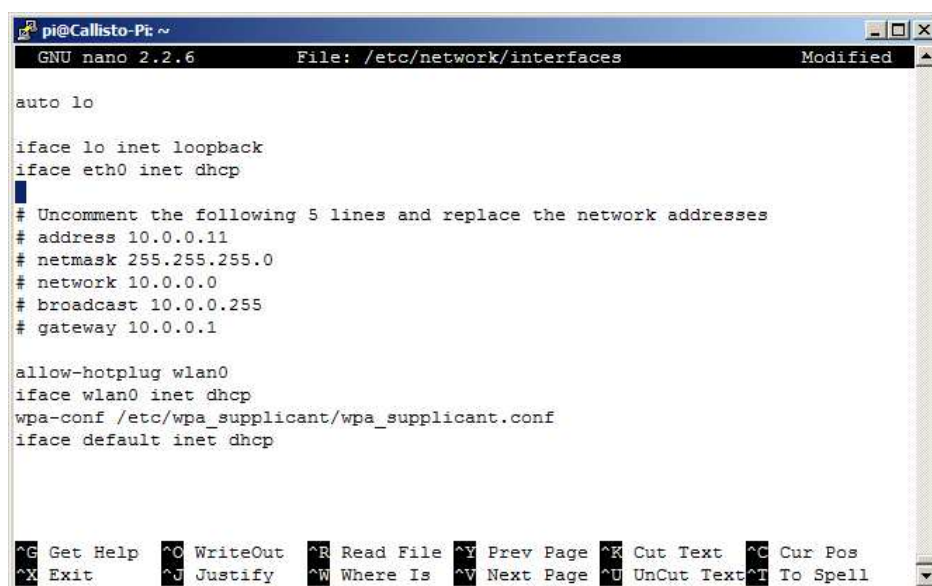
Destination: _____ (your network destination)

Gateway: _____ (your gateway address)

A.2. Edit the network configuration

Use the built-in editor nano to edit the network interface configuration file:

`sudo nano /etc/network/interfaces`



```
pi@Callisto-Pi: ~
GNU nano 2.2.6      File: /etc/network/interfaces      Modified

auto lo

iface lo inet loopback
iface eth0 inet dhcp

# Uncomment the following 5 lines and replace the network addresses
# address 10.0.0.11
# netmask 255.255.255.0
# network 10.0.0.0
# broadcast 10.0.0.255
# gateway 10.0.0.1

allow-hotplug wlan0
iface wlan0 inet dhcp
wpa-conf /etc/wpa_supplicant/wpa_supplicant.conf
iface default inet dhcp

^G Get Help  ^O WriteOut  ^R Read File ^Y Prev Page ^K Cut Text  ^C Cur Pos
^X Exit      ^J Justify   ^W Where Is ^V Next Page ^U UnCut Text ^T To Spell
```

Using the keyboard cursors, move to the end of the line that reads:

iface eth0 inet dhcp

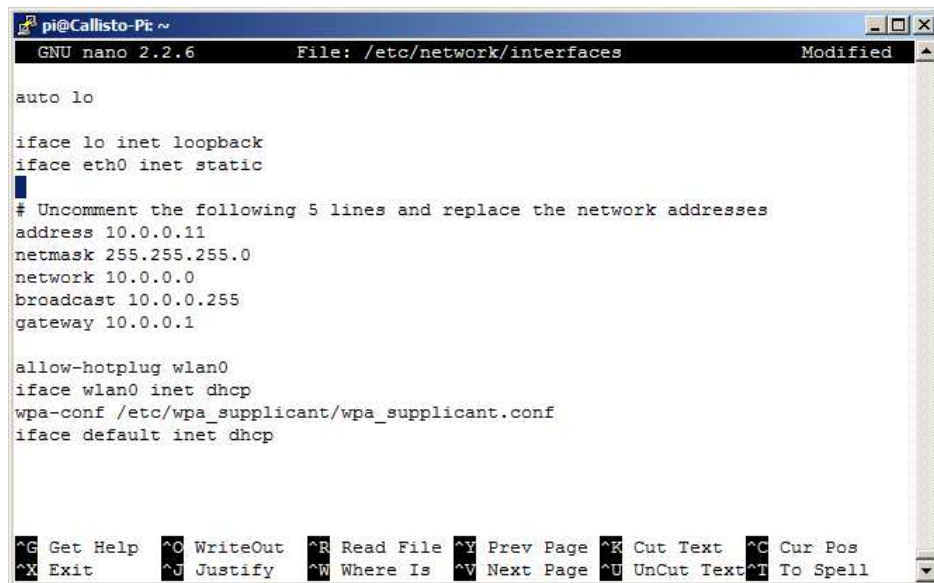
Replace dhcp with static, as in:

iface eth0 inet static

Directly below the `iface` line uncomment (delete the `#` character) the following lines and replace the address parameters with those you obtained previously. Do not enter the text in parentheses below:

address 10.0.0.11 (use the inet address)
netmask 255.255.255.0 (use the subnet mask)
network 10.0.0.0 (use the network destination)
broadcast 10.0.0.255 (use the broadcast IP range)
gateway 10.0.0.1 (use the gateway address)

The **address** field is the static IP address to be assigned to the RPi. It does not necessarily have to be the address originally assigned by the LAN router but it must be within the router's network range.



```
pi@Callisto-Pi ~
GNU nano 2.2.6      File: /etc/network/interfaces      Modified

auto lo

iface lo inet loopback
iface eth0 inet static

# Uncomment the following 5 lines and replace the network addresses
address 10.0.0.11
netmask 255.255.255.0
network 10.0.0.0
broadcast 10.0.0.255
gateway 10.0.0.1

allow-hotplug wlan0
iface wlan0 inet dhcp
wpa-conf /etc/wpa_supplicant/wpa_supplicant.conf
iface default inet dhcp

^G Get Help  ^O WriteOut  ^R Read File  ^Y Prev Page  ^K Cut Text  ^C Cur Pos
^X Exit      ^J Justify   ^W Where Is  ^V Next Page  ^U UnCut Text ^T To Spell
```

Your console should look similar to above but it will have your parameter values.

Now press CTRL+X (Exit), Y (Yes) and then ENTER to save the changes.

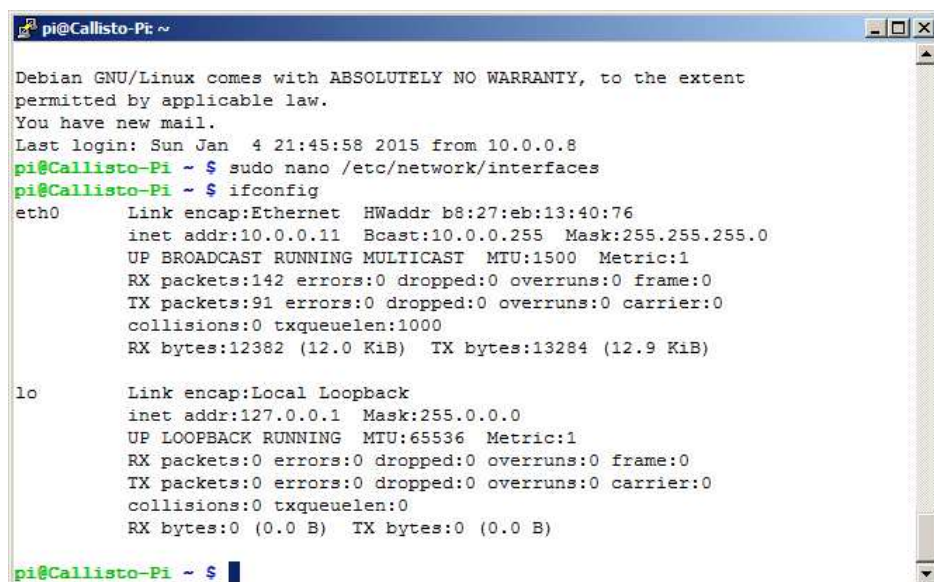
Reboot the RPi so the changes can take effect:

```
sudo reboot
```

A.3. Check Static IP Configuration

After the RPi reboots, restart the PuTTY session (right-click the title bar at top of PuTTY window and select Restart Session), log into the RPi and enter:

```
ifconfig
```



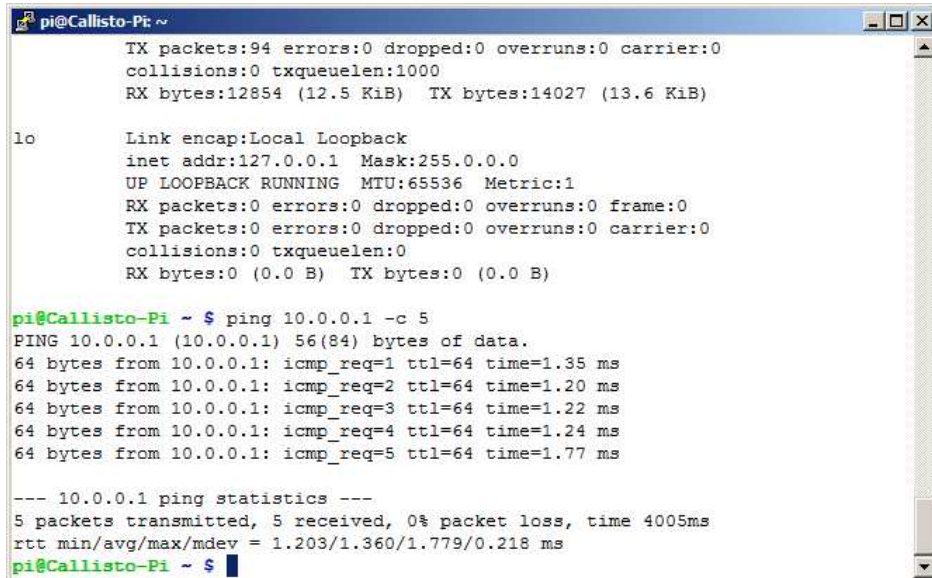
```
pi@Callisto-Pi ~
Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
You have new mail.
Last login: Sun Jan  4 21:45:58 2015 from 10.0.0.8
pi@Callisto-Pi ~ $ sudo nano /etc/network/interfaces
pi@Callisto-Pi ~ $ ifconfig
eth0      Link encap:Ethernet  HWaddr b8:27:eb:13:40:76
          inet addr:10.0.0.11  Bcast:10.0.0.255  Mask:255.255.255.0
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:142 errors:0 dropped:0 overruns:0 frame:0
          TX packets:91 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:12382 (12.0 KiB)  TX bytes:13284 (12.9 KiB)

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          UP LOOPBACK RUNNING  MTU:65536  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)

pi@Callisto-Pi ~ $
```

Double-check your work by pinging the gateway (the -c 5 command line switch indicates to ping 5 times. Note: Without the -c 5 switch the address will be pinged continuously. To stop continuous ping, press CTRL+C). Also, be sure to use the IP address of your gateway (router) and not the one shown here:

```
ping 10.0.0.1 -c 5
```



```
pi@Callisto-Pi ~  
TX packets:94 errors:0 dropped:0 overruns:0 carrier:0  
collisions:0 txqueuelen:1000  
RX bytes:12854 (12.5 KiB) TX bytes:14027 (13.6 KiB)  
  
lo    Link encap:Local Loopback  
      inet addr:127.0.0.1 Mask:255.0.0.0  
      UP LOOPBACK RUNNING MTU:65536 Metric:1  
      RX packets:0 errors:0 dropped:0 overruns:0 frame:0  
      TX packets:0 errors:0 dropped:0 overruns:0 carrier:0  
      collisions:0 txqueuelen:0  
      RX bytes:0 (0.0 B) TX bytes:0 (0.0 B)  
  
pi@Callisto-Pi ~ $ ping 10.0.0.1 -c 5  
PING 10.0.0.1 (10.0.0.1) 56(84) bytes of data:  
64 bytes from 10.0.0.1: icmp_req=1 ttl=64 time=1.35 ms  
64 bytes from 10.0.0.1: icmp_req=2 ttl=64 time=1.20 ms  
64 bytes from 10.0.0.1: icmp_req=3 ttl=64 time=1.22 ms  
64 bytes from 10.0.0.1: icmp_req=4 ttl=64 time=1.24 ms  
64 bytes from 10.0.0.1: icmp_req=5 ttl=64 time=1.77 ms  
  
--- 10.0.0.1 ping statistics ---  
5 packets transmitted, 5 received, 0% packet loss, time 4005ms  
rtt min/avg/max/mdev = 1.203/1.360/1.779/0.218 ms  
pi@Callisto-Pi ~ $
```

The pings should be successful with no packet loss. If not successful, then your setup is incorrect. Recheck each step above. If necessary, you can revert to DHCP by reversing the steps or by looking at your screenshots before the changes.

You must reboot after making any interface changes:

```
sudo reboot
```

Alternately, instead of reboot, you also can simply stop and restart the RPi network:

```
sudo /etc/init.d/networking stop  
sudo /etc/init.d/networking start
```

Appendix B ~ Install Wireless LAN (WLAN)

Adding a wireless LAN connection to the RPi requires only a USB wireless access device (also called WLAN dongle and Wi-Fi dongle) and some changes to the network interface configurations. Note: A USB BlueTooth dongle is physically identical to the Wi-Fi dongle but is not compatible with this application. Most Wi-Fi dongles are marked 802.11n.

The following steps assume the RPi is initially connected to the LAN through a wired Ethernet cable. DO NOT plugin the Wi-Fi dongle until told to do so. As you go through the following steps, take screenshots before and after making changes – this will help in case you need to reverse your changes.

It should be remembered that a Wi-Fi dongle derives power from the RPi USB port and this power is in addition to that required by the RPi itself. The dongle should be plugged into the USB port BEFORE power is applied to the RPi; otherwise, the RPi will reboot because of the momentary voltage drop on its power bus. This is a design deficiency in the RPi and can result in program corruption.

B.1. WLAN Dongle

WLAN dongles are inexpensive and easy to obtain; for example, the Edimax EW-7811Un Nano, 150Mbps 802.11n Wi-Fi USB Adapter costs 7 USD. These devices have a very small antenna so their range is limited but ≥ 3 m between the dongle and a wireless router or wireless access point should be achievable in most situations.



Caution: Some WLAN dongles use power management by default and they will go into sleep mode after a period of inactivity. Sleep mode is manifested as a “dead” Wi-Fi connection from which the device will not recover without rebooting the RPi. This is a well-known problem when these devices are used in the RPi, and the solution depends on the chipset used in the dongle itself. The software image includes a configuration file that solves this problem for the RealTek 8192cu/RTL8188CUS chipset used in many Wi-Fi dongles. If your Wi-Fi dongle has that chipset, you should not have any problems. If your WLAN device does not operate reliably then you will have to revert to a wired network connection.

B.2. Wi-Fi Setup Details

Check the configuration of the Wi-Fi access point to which you plan to connect. You will need to determine:

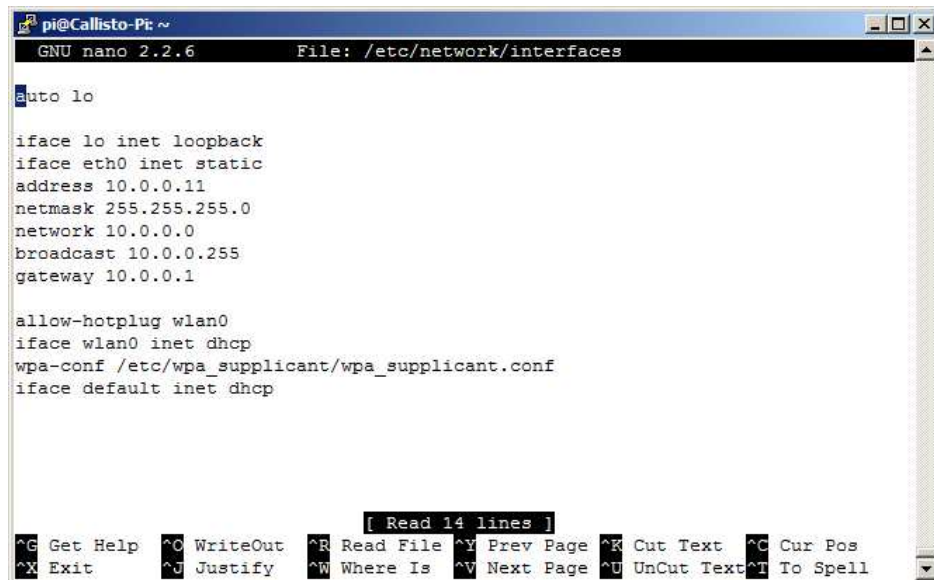
- ⚙ SSID
- ⚙ Password (or key)
- ⚙ Encryption type and method (for example, WPA and TKIP shared-key encryption)

Procedures for determining these parameters vary widely so you will need to refer to the wireless access point user guide or do online research. The setup described in the following paragraphs assumes your Wi-Fi network broadcasts the SSID (Service Set Identifier).

B.3. Setup W-Fi Configuration

Do not yet plug in the Wi-Fi dongle. Log into the RPi and enter the following commands:

```
sudo nano /etc/network/interfaces
```



```
pi@Callisto-Pi: ~
GNU nano 2.2.6      File: /etc/network/interfaces

auto lo

iface lo inet loopback
iface eth0 inet static
address 10.0.0.11
netmask 255.255.255.0
network 10.0.0.0
broadcast 10.0.0.255
gateway 10.0.0.1

allow-hotplug wlan0
iface wlan0 inet dhcp
wpa-conf /etc/wpa_supplicant/wpa_supplicant.conf
iface default inet dhcp

[ Read 14 lines ]
^G Get Help  ^O WriteOut  ^R Read File ^Y Prev Page ^K Cut Text  ^C Cur Pos
^X Exit      ^J Justify   ^W Where Is  ^V Next Page ^U UnCut Text ^T To Spell
```

Note the following lines. Do not change them:

```
auto lo
iface lo inet loopback
iface eth0 inet static
```

The above form the basic wired network interface configuration in which the RPi uses a static IP address (see Appendix A). The lines that immediately follow show the static IP configuration. If your RPi is setup to use DHCP, the third line of text will read as follows and there will be no addressing:

```
iface eth0 inet dhcp
```

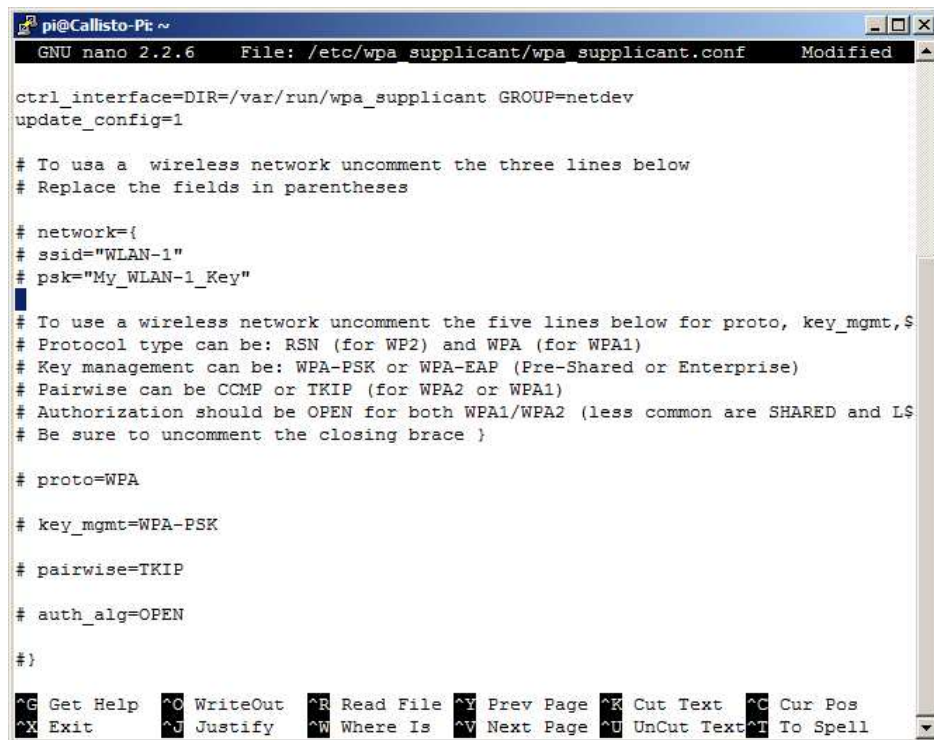
Also note the following lines, which provide basic WLAN configuration details. Do not change them. The WLAN configuration is defined by the wpa_supplicant.conf file:

```
allow-hotplug wlan0
iface wlan0 inet dhcp
wpa-conf /etc/wpa_supplicant/wpa_supplicant.conf
iface default inet dhcp
```

Press CTRL+X (Exit) to exit the nano editor.

It is necessary to edit the configuration file. At the RPi prompt, enter the following command:

```
sudo nano /etc/wpa_supplicant/wpa_supplicant.conf
```



```
pi@Callisto-Pi: ~
GNU nano 2.2.6 File: /etc/wpa_supplicant/wpa_supplicant.conf Modified

ctrl_interface=DIR=/var/run/wpa_supplicant GROUP=netdev
update_config=1

# To use a wireless network uncomment the three lines below
# Replace the fields in parentheses

# network={
#   ssid="WLAN-1"
#   psk="My_WLAN-1_Key"
#
# To use a wireless network uncomment the five lines below for proto, key_mgmt, $
# Protocol type can be: RSN (for WPA2) and WPA (for WPA1)
# Key management can be: WPA-PSK or WPA-EAP (Pre-Shared or Enterprise)
# Pairwise can be CCMP or TKIP (for WPA2 or WPA1)
# Authorization should be OPEN for both WPA1/WPA2 (less common are SHARED and L$
# Be sure to uncomment the closing brace }

# proto=WPA

# key_mgmt=WPA-PSK

# pairwise=TKIP

# auth_alg=OPEN

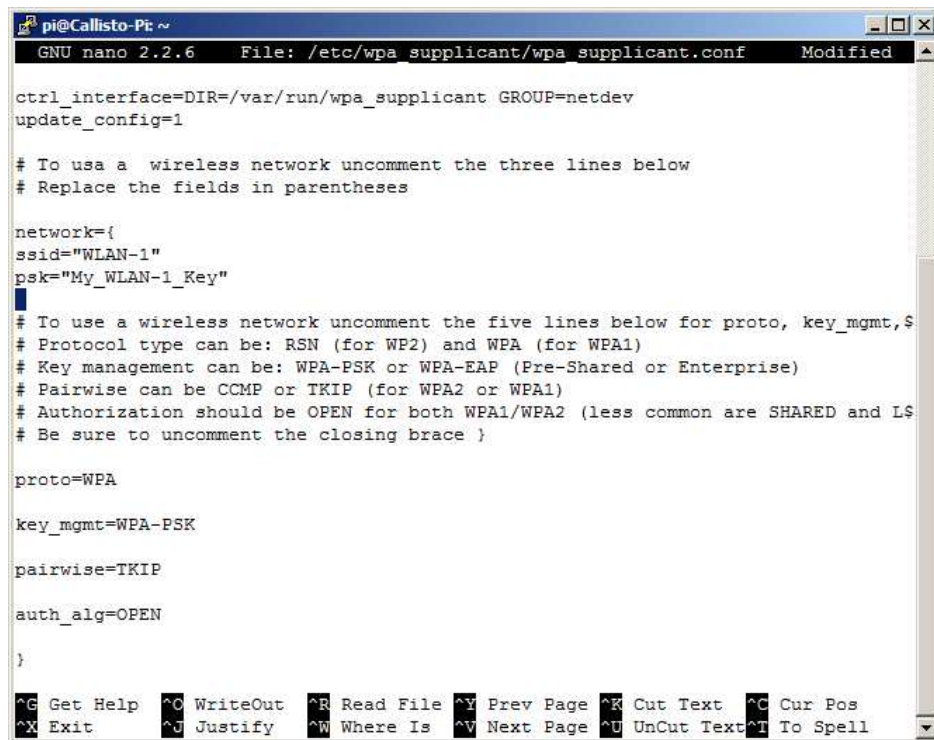
#}

^G Get Help ^O WriteOut ^R Read File ^Y Prev Page ^K Cut Text ^C Cur Pos
^X Exit ^J Justify ^W Where Is ^V Next Page ^U UnCut Text ^T To Spell
```

Note the following two lines. Do not change them:

```
ctrl_interface=DIR=/var/run/wpa_supplicant GROUP=netdev
update_config=1
```

The configuration file supplied with the RPi software image includes a number of additional lines, all commented out (deactivated) with the # character. Use the keyboard arrow keys to navigate the text and then make the changes necessary for your wireless network. The first two parameters, ssid and psk, are the SSID and PASSWORD values, and proto, key_mgmt, pairwise and auth_alg are the Encryption type and method mentioned in par. B.2. To activate the WLAN, delete the # character and edit the values shown according to your network details. When finished, the configuration file should look something like this:



```
pi@Callisto-Pi: ~
GNU nano 2.2.6 File: /etc/wpa_supplicant/wpa_supplicant.conf Modified

ctrl_interface=DIR=/var/run/wpa_supplicant GROUP=netdev
update_config=1

# To use a wireless network uncomment the three lines below
# Replace the fields in parentheses

network={
ssid="WLAN-1"
psk="My_WLAN-1_Key"

# To use a wireless network uncomment the five lines below for proto, key_mgmt, $
# Protocol type can be: RSN (for WPA2) and WPA (for WPA1)
# Key management can be: WPA-PSK or WPA-EAP (Pre-Shared or Enterprise)
# Pairwise can be CCMP or TKIP (for WPA2 or WPA1)
# Authorization should be OPEN for both WPA1/WPA2 (less common are SHARED and L$
# Be sure to uncomment the closing brace }

proto=WPA

key_mgmt=WPA-PSK

pairwise=TKIP

auth_alg=OPEN

}

^G Get Help ^O WriteOut ^R Read File ^Y Prev Page ^K Cut Text ^C Cur Pos
^X Exit ^J Justify ^W Where Is ^V Next Page ^U UnCut Text ^T To Spell
```

When done editing the file, press CTRL+X (Exit), Y (Yes) and ENTER to save and exit the configuration file.

If you have more than one Wi-Fi network at your station, you can add the details for each network in the wpa_supplicant.conf file. The RPi will then connect to the one with the best signal. For a setup with multiple networks, the text lines “network = { additional network details }” will need to be determined and specified for each network.

Now, shut down the RPi:

```
sudo halt
```

All LED indicators on the RPi board except the red power LED will extinguish when the shutdown is complete. When the shutdown is complete, remove power.

B.4. Install the WLAN Dongle

With power disconnected from the RPi, unplug the Ethernet cable and plug the WLAN dongle into any USB port on the RPi. Connect power to RPi. As it boots, the power LED (red) will be steady and the Activity LED should flash. After a moment, the RPi should automatically connect to your wireless access point. The RPi is setup to use DHCP and will request an IP address from the router. Most WLAN dongles have a status LED, which should flash when initialized. The LED will flash at about 1 Hz rate with occasional shorter, irregular flashes indicating activity. If the status LED does not light at all or continues to flash at only 1 Hz rate for more than a minute (with no occasional flashes), there may be a problem in your setup.

You will not be able to log into the RPi until you determine the wireless IP address and then setup the SSH client (PuTTY) to use that address. Check your router or use a network scanning program (for example, SoftPerfect

Network Scanner, {NetScan}) to find the hostname (same hostname as the wired network connection but this time it most likely will have a different IP address).

If the RPi fails to appear on the network, you can plug the Ethernet cable back in, log into the wired Ethernet interface and double-check the above steps. You most likely made a typing error. After finding and fixing the error, you can either restart the network interface or reboot the RPi. To restart the network interface (without rebooting the RPi), at the prompt enter

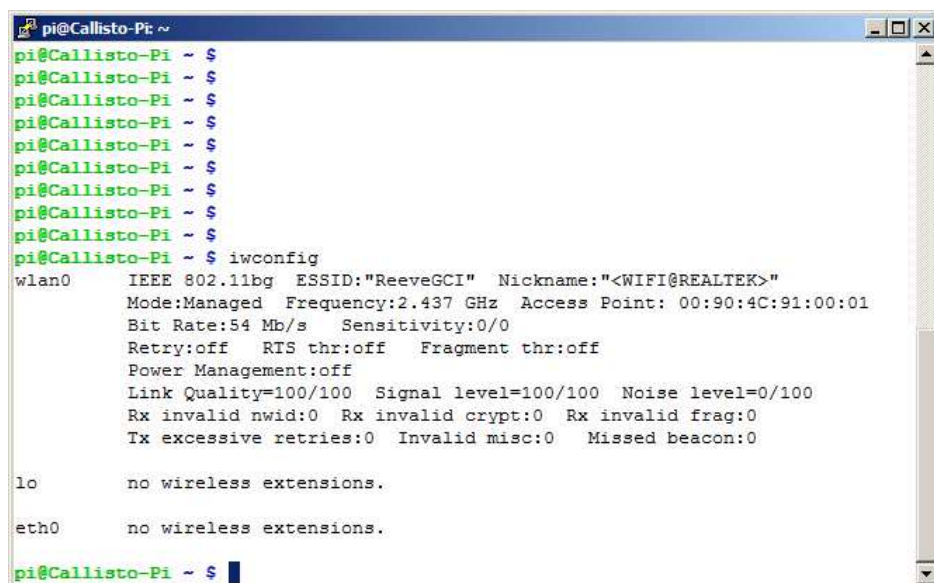
```
sudo /etc/init.d/networking restart
```

Disconnect the wired Ethernet cable and log into the wireless interface using the wireless IP address. Remember, do not insert or remove the WLAN dongle with power applied to the RPi, but it is okay to remove and install the wired LAN connection with power on.

It is recommended that either wireless LAN or wired LAN be used but not both at the same time. If wired LAN is to be used, remove the WLAN dongle (with RPi power off). If wireless LAN is to be used, remove the wired LAN connection.

After logging into RPi, you can check the wireless connection quality. At the RPi prompt, enter:

```
iwconfig
```



```
pi@Callisto-Pi ~ $
pi@Callisto-Pi ~ $
pi@Callisto-Pi ~ $
pi@Callisto-Pi ~ $
pi@Callisto-Pi ~ $
pi@Callisto-Pi ~ $
pi@Callisto-Pi ~ $
pi@Callisto-Pi ~ $
pi@Callisto-Pi ~ $
pi@Callisto-Pi ~ $
pi@Callisto-Pi ~ $
pi@Callisto-Pi ~ $ iwconfig
wlan0      IEEE 802.11bg  ESSID:"ReeveGCI"  Nickname:"<WIFI@REALTEK>"
          Mode:Managed  Frequency:2.437 GHz  Access Point: 00:90:4C:91:00:01
          Bit Rate:54 Mb/s   Sensitivity:0/0
          Retry:off   RTS thr:off   Fragment thr:off
          Power Management:off
          Link Quality=100/100  Signal level=100/100  Noise level=0/100
          Rx invalid nwid:0  Rx invalid crypt:0  Rx invalid frag:0
          Tx excessive retries:0  Invalid misc:0  Missed beacon:0

lo         no wireless extensions.

eth0       no wireless extensions.

pi@Callisto-Pi ~ $
```

To the right of the **wlan0** interface the details include the SSID, frequency, bit-rate, link quality, signal level and noise level plus other information about the wireless connection. To see packet information and IP addresses for all connected interfaces enter (in the following example, both the wired and wireless connections are active):

```
ifconfig
```

```
pi@Callisto-Pi ~  
pi@Callisto-Pi ~ $ ifconfig  
eth0      Link encap:Ethernet  HWaddr b8:27:eb:13:40:76  
          inet addr:10.0.0.11  Bcast:10.0.0.255  Mask:255.255.255.0  
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1  
          RX packets:2650 errors:0 dropped:3 overruns:0 frame:0  
          TX packets:1176 errors:0 dropped:0 overruns:0 carrier:0  
          collisions:0 txqueuelen:1000  
          RX bytes:370496 (361.8 KiB)  TX bytes:698940 (682.5 KiB)  
  
lo        Link encap:Local Loopback  
          inet addr:127.0.0.1  Mask:255.0.0.0  
          UP LOOPBACK RUNNING  MTU:65536  Metric:1  
          RX packets:26 errors:0 dropped:0 overruns:0 frame:0  
          TX packets:26 errors:0 dropped:0 overruns:0 carrier:0  
          collisions:0 txqueuelen:0  
          RX bytes:2704 (2.6 KiB)  TX bytes:2704 (2.6 KiB)  
  
wlan0     Link encap:Ethernet  HWaddr 00:e3:a7:29:ba:98  
          inet addr:10.0.0.37  Bcast:10.0.0.255  Mask:255.255.255.0  
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1  
          RX packets:2386 errors:0 dropped:53 overruns:0 frame:0  
          TX packets:21 errors:0 dropped:0 overruns:0 carrier:0  
          collisions:0 txqueuelen:1000  
          RX bytes:804178 (785.3 KiB)  TX bytes:2977 (2.9 KiB)  
  
pi@Callisto-Pi ~ $
```

You also can obtain information about your network. At the prompt type:
netstat -nr

```
pi@Callisto-Pi ~  
pi@Callisto-Pi ~ $  
pi@Callisto-Pi ~ $  
pi@Callisto-Pi ~ $ iwconfig  
wlan0     IEEE 802.11bg  ESSID:"ReeveGCI"  Nickname:"<WIFI@REALTEK>"  
          Mode:Managed  Frequency:2.437 GHz  Access Point: 00:90:4C:91:00:01  
          Bit Rate:54 Mb/s   Sensitivity:0/0  
          Retry:off   RTS thr:off   Fragment thr:off  
          Power Management:off  
          Link Quality=100/100  Signal level=100/100  Noise level=0/100  
          Rx invalid nwid:0  Rx invalid crypt:0  Rx invalid frag:0  
          Tx excessive retries:0  Invalid misc:0  Missed beacon:0  
  
lo        no wireless extensions.  
  
eth0      no wireless extensions.  
  
pi@Callisto-Pi ~ $ netstat -nr  
Kernel IP routing table  
Destination Gateway Genmask Flags MSS Window irtt Iface  
0.0.0.0 10.0.0.1 0.0.0.0 UG 0 0 0 eth0  
10.0.0.0 0.0.0.0 255.255.255.0 U 0 0 0 eth0  
10.0.0.0 0.0.0.0 255.255.255.0 U 0 0 0 wlan0  
You have new mail in /var/mail/pi  
pi@Callisto-Pi ~ $
```

At the bottom of the window is a routing table. In this example, the wired Ethernet cable was left connected so it shows both the wired Ethernet (eth0) and wireless LAN connection (wlan0).

The following commands also can be used to check the quality of the wireless connection:
sudo iwlist wlan0 scan

```
pi@Callisto-Pi ~  
pi@Callisto-Pi ~ $ sudo iwlist wlan0 scan  
wlan0 Scan completed :  
Cell 01 - Address: 00:90:4C:91:00:01  
ESSID:"ReeveGCI"  
Protocol:IEEE 802.11bg  
Mode:Master  
Frequency:2.437 GHz (Channel 6)  
Encryption key:on  
Bit Rates:54 Mb/s  
Extra:wpa_ie=dd180050f20101000050f20201000050f20201000050f2020000  
IE: WPA Version 1  
Group Cipher : TKIP  
Pairwise Ciphers (1) : TKIP  
Authentication Suites (1) : PSK  
Quality=100/100 Signal level=100/100  
Cell 02 - Address: 00:16:B6:4F:39:81  
ESSID:"GCI-2"  
Protocol:IEEE 802.11bg  
Mode:Master  
Frequency:2.412 GHz (Channel 1)  
Encryption key:on  
Bit Rates:54 Mb/s  
Extra:wpa_ie=dd180050f20101000050f20201000050f20201000050f2020000  
IE: WPA Version 1  
Group Cipher : TKIP  
Pairwise Ciphers (1) : TKIP  
Authentication Suites (1) : PSK  
Quality=0/100 Signal level=60/100  
pi@Callisto-Pi ~ $
```

Document information

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0.1 (Numerous additions based on model B, 9 Sep 2014)
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